(11) (A) No. 959169

(45) ISSUED Dec. 10, 1974

(52) CLASS 354-30
C.R. CL.

(19) (CA) # CANADIAN PATENT

(54) SYSTEM FOR THE ALLOCATION OF GAS AND LIQUID PRODUCTS RECOVERED FROM NATURAL GAS STREAMS

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(21) APPLICATION No. 124,116
(22) FILED Sep. 30, 1971

(30) PRIORITY DATE Nov. 20, 1970 (91,379) U.S.A.

No. OF CLAIMS 1

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Background of the Invention

Natural gas is produced from underground reservoirs through wells either alone (gas wells) or in conjunction with crude oil (oil wells). Almost always associated with gas produced from these sources are recoverable liquid hydrocarbons, water, and minor amounts of non-hydrocarbon gaseous constituents (such as hydrogen sulfide, nitrogen, and carbon dioxide). The gas stream is conditioned and processed in many ways between the time it leaves the well and the various constituents of the stream are sold, producing revenue. The result is that the volumes of products sold cannot be directly related to the volumes produced from the well without a considerable amount of mathematical manipulation of the available volume and price data.

The possible variations from one physical gathering system to another are practically infinite in number and scope. Added to this is the fact that the gas and products are processed and sold under contracts which vary as to their conditions and requirements on the seller, the purchaser, and the processor. The combination of these two factors tends to make each allocation situation approach unique. The allocation process must take into account each and every physical occurrence in the gas stream between the producing well and sales point, as well as the conditions and requirements of the contracts involved, and calculate the equitable share of each product for each entity furnishing a part of the total gas stream. Allocation procedures are dynamic by nature and standardized calculation procedures, to be useful, must be flexible enough to allow for changes which take place in the situation, e.g. the addition or removal of wells or changes in the gas processing method.

Prior to the advent of the electronic computer, these allocation procedures were performed manually by clerks using

calculators and the very tedious and laborious calculation formulas developed for each individual situation. In large fields the allocation procedure could require in excess of 40-50 man-hours per month to perform.

The variability in procedures and the dynamic nature of the allocation situation made early attempts at computerization limited successes at best. Each field system was generally approached on a single allocation system basis. Even then, the dynamics also caused frequent logic changes in the computer programs to keep up with the physical changes occurring in the gas system resulting in programming effort disproportionate to the advantages derived.

The primary objective of the invention is to achieve automation through a general computer system which would offer the advantages of speed, accuracy, and economy. The results of the allocation procedures are available sooner with the computer system. The use of the digital computer to make the calculation results in the ultimate in accuracy of computation, and the desired results are available at lower unit cost than from a manual system. A further object of the invention is to permit universal handling of multiple physical allocation situations and dynamics with a general purpose computer system requiring no internal programming modification to reflect changes which take place in the physical gas gathering and processing complex.

Summary of the Invention

This invention is a system for the allocation of gas and liquid products through field gathering and processing. The gas stream is carried successively from the producing well through various measuring and processing points, all encountered use or disposition points, and down to the point of entry to a gas processing plant or to the point of sale if the gas is not processed in a plant. The invention takes as input data the

various measured volumes, stream analyses, factors, known estimates, and formulas for the calculation of various gas dispositions which take place in the system. Through the use of a defined and coded procedure applying to that particular system, it performs all the mathematical calculations and manipulations of data required. The output results are the allocated volumes of gas and products due to each entity providing a portion of the total stream flowing through the field. The generalized nature of the system permits its use in performing these functions for all fields, regardless of the widely varied physical makeup and required functions from field to field. This is accomplished by the use of a set of generalized functions, each of which is coded into the calculation program of the system as an independent section or subroutine, callable and performable in unlimited frequency and sequence. These general functions cover the spectrum of all types of operations necessary in the process of allocation. The set of functions which is required to perform any given allocation is coded as a special type record of the system master file. This permits its updating to account for the changes which occur in the field operation through the relatively simple procedure of file maintenance rather than requiring internal logic changes in the computer programs. The actual allocation process is performed in the calculation program of the system through the insertion of input data into a large two-dimensional array constructed in the computer core. The function subroutines then direct the various calculations, movement and manipulation of data in the array until values representing final allocated volumes are obtained. The data is then stored on magnetic tape or disk devices and reports are prepared through standard data processing procedures. Other ordinary data processing programs may be made a part of the overall system to perform functions

such as the input of monthly transaction data to the calculation program, sorting and printing of various data at several points in the system, and normal tests and validation of data.

Brief Description of the Drawings

FIG. 1 presents a hypothetical field gas gathering system showing some typical sources and dispositions of gas which bear directly on allocation procedures.

FIGS. 2, 3, 4, 5, 6, and 7 present the design logic of typical generalized allocation function subroutines used in the system shown in FIG. 1.

Description of the Preferred Embodiment(s)

Raw gas streams pass from oil and/or gas wells into and through gathering systems of diverse constitution and orientation. There are numerous possibilities for the transformation of the character of the stream and the partial use or disposition of the stream as it flows through a given system. For example, objectionable components may be removed from the gas, a portion of the stream may be required for fuel to operate various units of the system, and various useful products may be recovered from the gas for sale.

The ultimate result is that after all the necessary and desirable operations take place, the valuable products of the stream are sold or otherwise disposed of, resulting in revenue attributable to the producing entities which have furnished the gas to the system. The purpose of allocation procedures is to assure that the volumes of products and/or their value is equitably distributed to the supplying entities or, in other words, that each involved owner interest receives his fair share of the proceeds.

The invention is described in conjunction with the embodiment presented in FIG. 1 which shows a typical field gathering system. Gas enters from groups of wells A, B, C, D,

E, and F. Note that groups A-D are gas wells while groups E and F produce both crude oil and gas. Wells 1-5 are in group A; wells 6-9, in group B; wells 10 and 11, in group C; wells 12-18, in group D; wells 19-23, in group E; and wells 24-26, in group F. The various wells are placed in their respective groups primarily on the basis of stream pressure. Each group or sub-system has to be adjusted to the lowest pressure well present in the group. The gas production from each well is measured by flow meters m prior to being combined with gas from other wells in the group or with other groups. Flow meters m also measure any input or output of gas into or from the system at the other locations indicated in FIG. 1.

Referring to group A, wells 1-5 produce gas at 1000 psi that is combined to form stream 29 leading to dehydrator unit 30. Fuel required by dehydrator 30 in its operation is taken from output stream 31 as indicated by return line 32. Meter m in line 31 measures the fuel consumed by dehydrator 30.

The group B wells produce gas at 500 psi and their pressure must be boosted prior to combining with the gas from the group A wells. The output from wells 6-9 is combined to form stream 33 leading to compressor 34 where the pressure is raised to the desired line value of 1000 psi. Output stream 35 from compressor 34 is measured by meter m and goes to dehydrator 30 where it is combined with the gas from group A. Fuel for compressor 34 is taken from output stream 35 as indicated by return line 36. Meter m in line 36 measures the fuel utilized by compressor 34.

Following output stream 31 from dehydrator 30, a junction is reached where gas is removed via line 37 for operation of a drilling rig. Meter m in line 37 measures the volume of gas provided the rig.

The gas continues to move through line 31 to the

connection points with lines 38 and 39. Here is a situation where some of the owners of this system have agreed to exchange gas with some other system under conditions mutually beneficial to both systems. Gas transferred to the other system is measured by meter m on line 38 and gas received is measured by meter m on line 39.

Next, gas produced by the group C wells is gathered by line 40 and connects with stream 31. Gas produced by wells 10 and 11 is already at 1000 psi so no pressure adjustment is required. Also, dehydration treatment is not necessary.

Referring now to group D, wells 12-18 produce high pressure, 2000 psi, gas that is subject to a different field processing arrangement. Here the gas is combined to form input stream 45 going to low temperature separator 46 which reduces the pressure of the gas. Energy thus released is used to refrigerate the gas to accomplish dehydration and to condense a liquid hydrocarbon product. The condensed hydrocarbon liquids pass via line 47 to storage tank 48. Some low pressure, 100 psi, gas results as a byproduct of stabilizing the liquid hydrocarbons and is output through line 49 to line 60 where it goes to the second stage of three-stage compressor 55. The main product is 1000 psi gas which forms output stream 50. Fuel required to operate separator 46 is taken from stream 50 by return line 51. Meter m in line 51 measures the gas utilized by separator 46 and meter m in line 50 measures the net volume of 1000 psi gas leaving separator 46. Downstream, it will be seen that line 52 branches off from line 50. Line 52 carried off gas for use as lift gas to aid in oil recovery.

The remaining segment of the gathering system consists of gas which has been produced from oil wells. Gas from groups E and F will normally be at a considerably lower pressure and will contain higher quantities of recoverable liquid hydrocarbons

than gas produced by wells A-D. The handling of the gas and its recovery is generally appreciably different as a result of these factors.

First, it will be noted that gas is introduced into wells 19 and 20 via lines 56 and 57 for lifting oil from the underground reservoir. This gas is measured by meters m in lines 56 and 57 prior to injection into each well. The output product from each of wells 19-23 (including injection gas) is combined to form stream 58 going to two-stage separator 59. One part of the gas recovered from separator 59 is 100 psi and is carried by line 60 to the second stage of compressor 55. The remainder of the gas recovered from separator 59 is 250 psi and is carried by line 61 to the third stage of compressor 55. Meters m in lines 60 and 61 measure the gas volumes thus distributed. Recovered liquid petroleum products are carried off by line 62 to storage tank 63.

Production from the group F wells is passed via line 64 to two-stage separator 65. One part of the gas product from separator 65 is 100 psi and is carried by lines 66 and 60 to the second stage of compressor 55. The other part of the gas product is 250 psi and is carried by lines 67 and 61 to the third stage of compressor 55. The liquid residue passes via line 68 to oil treater 69 where some 50 psi gas is obtained which is transported to the first stage of compressor 55 via line 72. The volume of the 50 psi gas is measured by meter m in line 72. The residual oil is carried via line 70 to storage tank 71.

After the gas supplied to compressor 55 is compressed to 1000 psi, it is carried via line 75 to line 50. Fuel used by compressor 55 is indicated by return line 76. Meters m in lines 75 and 76 measure the volume of gas introduced into line 50 and used by compressor 55, respectively. Additionally, some

low pressure gas is flared at compressor 55 as shown by metered output line 77.

Finally, line 50 connects to line 31 so that gas from all the wells is joined together. At valve 41 line 31 divides into line 31a going to a gas transmission line and line 31b going to a gas processing plant. The entire stream would go into one or the other of these branches with meters m measuring the volume of gas carried.

Now let us apply the processes of the present invention to perform the allocation procedures required in the field system shown in FIG. 1.

First, referring to the group B wells, the total volume of fuel consumed by compressor 34 must be allocated to each of wells 6-9 since they have gained the benefit of the compression. This is done by using the computer coding scheme referred to as the "Allocation Function" illustrated in TABLE I. By inserting the necessary data into the coding structure for the Allocation Function, the total volume of fuel consumed by compressor 34 will be charged to each of wells 6-9 in proportion to the initial volume of gas supplied by each well to compressor 34. Computer logic for carrying out the Allocation Function subroutine is given in FIG. 2.

959169

TABLE 1

ALLOCATION FUNCTION

MASTER FILE RECORD CODING SCHEME

ALOC	K	L	C_A	R_A	C_R	C_V	$E_1 \ldots E_L$	$A_1 \ldots A_K$

ALOC = Operating Code

K = Number of Allocation Points Involved ($K>0$)

L = Number of Exception Points to Allocation ($L\geq 0$)

C_A = Column Name Location of Total Volume to be Allocated

R_A = Row (Alloc. Pt.) Name Location of Total Volume to be Allocated

C_R = Column Name to Receive Computed (Allocated) Volumes

C_V = Column Name Location of Base or Theoretical Volumes

$E_1 \ldots E_L$ = Row (Alloc. Pt.) Names of the Exception Points

$A_1 \ldots A_K$ = Row (Alloc. Pt.) Names of Allocation Points

Referring to FIG. 2, the function and procedures performed by the Allocation Function are as follows:

Input data is introduced into block 80 to initiate the subroutine. The actual volume to be allocated is determined in block 81. If the actual volume is zero, the subroutine is terminated by following the YES line from decision point 82 to block 94. If there is an actual volume, the NO line is followed to decision point 83. If L=0, i.e. there are no exception points, the YES line is followed to block 84. If there are exception points to consider, the NO line is followed to block 85 where the exception volume is totalized.

$$VOL_{(C_R,\ E_1)} = VOL_{(C_R,\ E_1)} + VOL_{(C_V,\ E_1)} \text{ etc. for } (E_2 \ldots E_L)$$

The actual volume (net) is calculated in block 86 by subtracting the total exception volume from the total allocation volume.

$$ACT\ VOL = VOL_{(C_A,\ R_A)} - [VOL_{(C_V,\ E_1)} + \ldots . + VOL_{(C_V,\ E_L)}]$$

The indexes are changed and the Base Volume accumulator set to 0 in block 84. The Base Volume is computed by looping through block 87 until all K points have been used.

$$BAS\ VOL = VOL_{(C_V,\ A_1)} + VOL_{(C_V,\ A_2)} + \ldots . VOL_{(C_V,\ A_K)}$$

When K=0, the YES line is followed from decision point 88 to decision point 89. If the BAS VOL is something other than zero, an allocation factor is computer according to block 90.

$$FACTOR = \frac{ACT\ VOL}{BAS\ VOL}$$

Three steps take place in block 91. A theoretical volume is calculated; this volume is added to whatever volume may already be present at the receiving point in the array and the theoretical volume is deducted from the actual volume.

$VOL_{(C_R,\ A_1)} = VOL_{(C_R,\ A_1)} + [FACTOR \times VOL_{(C_V,\ A_1)}]$ etc. for $(A_1 \ldots . A_K)$ and

$ACT\ VOL = ACT\ VOL - T.\ VOL$

When K=0, the YES line is followed from decision point 92 to block 93 where the final allocated volume is stored at its code point in the array and the subroutine is terminated.

An example of the coding required to accomplish this follows:

ALOC/0004/0000/SYSF/1F01/SYSF/MVCL/7W06/7W07/7W08/7W09

where "1F01" is the code point for the fuel used by compressor 34 and "7W06," "7W07," "7W08," and "7W09" are code points for wells 6-9.

This coded statement tells the calculation program to call program section ALOC and perform it with the inserted

data. There are four points for which the allocation is to be made and there are zero exception points. The volume to be allocated will be found in the array at the column marked SYSF (system fuel) at code point 1F01. The calculated allocated volumes are to be placed in the array under SYSF at each of points 7W06, 7W07, 7W08, and 7W09. The allocation will be made based on the volumes present under the column called MVOL (metered volume) for each of the four points involved. The program then runs through the logic for the subroutine determining the share of compressor fuel chargeable to each of wells 6-9 and stores this data in the array for future use.

Turning to dehydrator unit 30, the fuel metered on line 32 must be allocated among all the wells benefiting from this treatment. Thus, fuel should be charged to each of wells 1-9 based on the portion of gas they provided to dehydrator 30. This would involve a second charge to the group B wells which can be kept separate or combined with the charge relating to compressor 34. The same allocation function given above would be used except that the fuel would now be divided among nine points rather than four. The coding for this would be:

ALOC/0009/0000/SYSF/1F02/SYSF/MVOL/7W01
/7W02/7W03/7W04/7W05/7W06/7W07/7W08/7W09

where "1F02" is the code point for the fuel used by dehydrator 30 and "7W01-7W09" are code points for wells 1-9.

Now, referring to the gas output via line 37 to the drilling rig, assume that contractual arrangements have been made with the owners of well 2 to obtain gas as required to operate the rig. The measured volume of gas passed through line 37 then must be charged to well 2, but not to any other wells in groups A and B.

This is done by use of a coding function called "Point Move" which moves an entry from one array point to another array

point. The Point Move Function is given in TABLE II and the computer logic for it is set forth in FIG. 3.

TABLE II

POINT MOVE FUNCTION

MASTER FILE RECORD CODING SCHEME

PMOV	S	C_V	R_V	C_R	R_R

PMOV = Operating Code

S = Function Sign:
- "PLUS" = Value to be Added to Value in Fld.
- "SUBT" = Value to be Subtracted from Value in Fld.
- "MOVE" = Value to Overlay Value in Fld.

C_V = Column Name Location of Data to be Moved

R_V = Row (Alloc. Pt.) Name Location of Data to be Moved

C_R = Column Name Location of Receiving Field

R_R = Row (Alloc. Pt.) Name Location of Receiving Field

Referring to FIG. 3, the function and procedures performed by PMOV are as follows:

Values are entered and indexed according to block 100. The function sign S is then tested at three-way decision point 101. If S = MOVE, calculations are performed as shown in block 102 and the volume entry is simply moved to another point in the array. If S = SUBT, calculations are performed as shown in block 103 and the volume entry is moved to another point and subtracted from the volume already there. If S = PLUS, calculations are performed according to block 104 and the volume entry is moved to another point and added to the volume already shown for that point. Whichever route is followed, the subroutine is

terminated as shown in block 105 after the data shift is accomplished and the results are stored.

Following the coding scheme shown in TABLE II:

PMOV/MOVE/MVOL/1S01/SALE/7W02

where "1S01" is the code point for the sale of gas via line 37 to the drilling rig and "7W02" is the code point for well 2.

This coding tells the calculation program to call the PMOV section and perform it using the coded data. The volume of gas measured on line 37 is entered under "MVOL." The computer then transfers this entry to code point "7W02" where it is placed under the column called "SALE." The "MOVE" means that the entry is transferred, replacing any value already present under "SALE."

Referring next to the gas exchange represented by output line 38 and input line 39, assume that the owner of well 9 has contracted for and participates in the exchange but the other well owners do not. Therefore, any gain or loss of gas due to the exchange must be added to or subtracted from the output for well 9.

The Point Move Function is again used in this situation since a simple shift from one array point to another is all that is required. Using TABLE II, two separate codings are required:

PMOV/SUBT/MVOL/1E01/EXCH/7W09

and

PMOV/PLUS/MVOL/1E02/EXCH/7W09

where "1E01" is the code point for line 38, "1E02" is the code point for line 39, and "7W09" is the code point for well 9.

The former coding represents the situation where gas leaves the system via line 38 and the latter coding covers the case where gas is introduced via line 39. In both cases, entries made under "MVOL" are transferred to the code point for

well 9, i.e. 7W09, and placed under the column called "EXCH." When gas is being transferred away from the system, the volume is subtracted from the value already in the column. When gas is being transferred to the system, the volume is added to the volume, if any, already there.

The wells of group C flow directly to sales by line 31a or to the gas processing plant by line 31B. As a result, wells 10 and 11 enter only into the final allocation procedure at the sales point or plant inlet. (Their effect will be discussed more fully later on.)

Referring to the group D wells, fuel required by low temperature separator 46 must be allocated to wells 12-18 in accordance with the volume input made by each well. This would be done by means of the Allocation Function previously illustrated using the following coding:

ALOC/0007/0000/SYSF/1F03/SYSF/MVOL
/7W12/7W13/7W14/7W15/7W16/7W17/7W18

where "1F03" is the code point for the fuel used by separator 46 and "7W12-7W18" are code points for wells 12-18.

Additionally, the liquid condensate recovered in storage tank 48 must be allocated to the wells providing the gas from which it was recovered. Since gas generally varies in content with respect to those components which make up the condensation product, it would not be equitable to allocate on the basis of gas volume alone. To be accurate one must consider the analysis of the gas and calculate a theoretical liquid volume based on the analysis with respect to each well.

The procedure to allocate the liquid volume would first involve the calculation of a theoretical liquid volume from each well using the "Theoretical Volume Function" represented in TABLE III and FIG. 4.

TABLE III

THEORETICAL VOLUME CALCULATION FUNCTION

MASTER FILE RECORD CODING SCHEME

TVOL	K	C_C	C_V	C_R	$A_1 \ldots A_K$

TVOL = Operating Code

K = Number of Allocation Points Involved ($K>0$)

C_C = Column Name; Location of Factor to be Used in Calc.

C_V = Column Name; Location of Data to be Used in Calc.

C_R = Column Name to Receive the Calculated Values

$A_1 \ldots A_K$ = Row Names of the Allocation Points Involved

Referring to FIG. 4, values are tabled and indexed in block 108. At decision point 109, determination is made regarding the value of K. If $K=0$, then the subroutine terminates. If $K\neq 1$, then calculations are performed according to block 110. The theoretical volume is calculated by multiplying the original data by a factor and adding the result to any value already there.

$$VOL_{(C_R,\ A_1)} = VOL_{(C_R,\ A_1)} + [VOL_{(C_V,\ A_1)} \times FACTOR_{(C_C,\ A_1)}]$$

The above step is then repeated for points $A_2 \ldots A_K$ as indicated by block 111.

The coding required to perform the Theoretical Volume Function in regard to the condensates recovered in tank 48 is as follows:

TVOL/0007/SEPT/MVOL/CONP/7W12
/7W13/7W14/7W15/7W16/7W17/7W18

where "SEPT" is the array code for the separator GPM factor and "7W12-7W16" are code points for the allocation locations.

This coding calls the program section called TVOL and has the computer perform it using the coded data. Volume calculations are to be performed for five different points using the analysis factors given under the array point SEPT. The theoretical condensate production (CONP) is then calculated by multiplying the metered gas volume for each well (MVOL) by its analysis factor.

Following the performance of the theoretical volume function as set forth above, the actual recovered condensate liquid would be allocated to the wells of group D using the previously illustrated Allocation Function. To complicate matters, assume that wells 17 and 18 have contracted to receive their full theoretical volume of condensate. The coding would then be:

ALOC/0007/0002/CONP/1X01/TMP1/CONP
/7W17/7W18/7W12/7W13/7W14/7W15/7W16

where "1X01" is the point name of the actual stored condensate and "TMP1" is a temporary storage column.

Wells 17 and 18 are listed as exception points and will automatically be eliminated from the allocation procedure, with the full theoretical volume replacing the allocated volume which would have been calculated.

The low pressure gas which is fed to compressor 55 by line 49 must also be credited to the wells which furnished the liquid product. Therefore, it will be allocated on the same basis as the liquid condensate, i.e. the allocation function is used based on the theoretical volume calculations. The coding would be the same as that given above, except for the column location of the gas to be allocated.

Downstream of separator 46, lift gas is removed via line 52. This volume of gas must be allocated to the wells that feed separator 46, i.e. wells 12-16. Allocation in this

instance will be based on the gas stream going to separator 46, rather than the theoretical liquid volume, using the Allocation Function. Coding would be:

ALOC/0007/0000/MVOL/1L01/GLFT/MVOL
/7W12/7W13/7W14/7W15/7W16/7W17/7W18

where "1L01" is the code point for the lift gas withdrawn through line 52.

This coding tells the computer to perform "ALOC" using the entry made at code point 1L01 under the column called MVOL (for gas lift). The original volume entry is to be allocated among code points 7W12-7W18 and stored under the column called GLFT using the metered volumes MVOL as the basis.

Referring to the group E wells, gas utilized by wells 19 and 20 must be charged to wells 19 and 20 and kept separate from the gas produced by the other group E wells. This is accomplished by a function called "Gas Lift" which is illustrated in TABLE IV and FIG. 5.

TABLE IV

GAS LIFT FUNCTION

MASTER FILE RECORD CODING SCHEME

GLFT	K	C_E	C_L	C_+	C_-	$A_1 \ldots A_K$	$B_1 \ldots B_K$

GLFT = Operating Code

K * = Number of Allocation Points Involved (K>0)

* There must be a corresponding point in the "B" set for each point in the "A" set.

C_E = Column Name; Location of Volume Entering Well

C_L = Column Name; Location of Volume Leaving Well

C_+ = Column Name; Receiving Location When Difference is Positive

C_- = Column Name; Receiving Location When Difference is Negative

$A_1 \ldots A_K$ = Row Names of Allocation Points Involved

$B_1 \ldots B_K$ = Row Names of Gas Lift Measuring Points Corresponding to the "A" Set

Referring to FIG. 5, the operational sequence is initiated by entering and indexing the values shown in block 115. If K=0, the YES line is followed from decision point 116 and operations are terminated. If K≠0, then the intermediate volume (called "IVOL") is calculated in block 117 according to the following equation:

$$IVOL = VOL_{(C_L,\ B_1)} - VOL_{(C_E,\ A_1)}$$

If IVOL is positive, the YES line is followed from decision point 118 to block 120 where the following calculations are made:

$$VOL_{(C_+,\ B_1)} = VOL_{(C_+,\ B_1)} + IVOL$$

If IVOL is zero or negative, the NO line is followed to block 119 where the following calculations are made:

$$VOL_{(C_{-},\ B_1)} = VOL_{(C_{-},\ B_1)} + IVOL$$

The outputs from blocks 119 and 120 both lead to block 121 where indexing is carried out so that the next allocation point will be considered, i.e. the procedure is repeated for points $A_2 \ldots A_K$.

An example of the coding would be:

GLFT/0002/MVOL/MVOL/FRMT/NJCT/7G19/7G20/7W19/7W20

where "7G19" and 7G20" are code points representing gas injection into wells 19 and 20, respectively, and 7W19 and 7W20 are code points for wells 19 and 20.

This coding tells the calculation program to call the subroutine GLFT and perform its logic with the above data. This in effect compares the volume of gas entering with the gas recovered from each well. If the latter is greater than the former, the difference is placed in the column called FRMT (formation gas). If the opposite is true, the negative amount is placed in the column called NJCT (injection gas).

The gas from the group E wells is recovered by means of separator 59 and is allocated to wells 19-23 on the basis of their gas-oil ratios. These factors are used with the Theoretical Volume Function previously discussed to determine the theoretical volume of gas produced by each well. This volume then becomes the theoretical basis for allocating the gas recovered by separator 59 in streams 60 and 61 using the Allocation Function.

Referring to the group F wells, gas obtained from separator 65 in streams 66 and 67 is allocated to wells 24-26 on a theoretical volume basis. First, the Theoretical Volume Function is used based on the gas-oil ratio of each well; then the Allocation Function is applied.

A special consideration in this segment of the system would be the gas (vapors) obtained via line 72 from oil treater 69. This gas is allocated on the basis of oil volume from each well involved since the oil is the source of the gas. The standard Allocation Function is used.

The gas from the group E and F wells, after leaving separators 59 and 64 and oil treater 69, flows to compressor 55 which boosts the pressure to the point where the gas may enter the rest of the system. Gas is also supplied to compressor 55 from the group D wells via stream 49. Here, again, fuel is utilized in the compression operation which must be allocated and charged against the wells furnishing the gas, i.e. wells 12-16 and 19-26. The theoretical volume calculations previously referred to are used with the Theoretical Volume Function to determine the theoretical volumes of gas produced by each well. This then becomes the theoretical basis for allocating the fuel used by compressor 55 using the Allocation Function. Gas flared at outlet 77 is similarly allocated and charged to the contributing wells.

At this point all the inputs and dispositions of gas indicated on FIG. 1 have been considered except for two final operations. Let us assume that the gas is sold directly to a transmission line. The gas throughput measured by meter m in line 31a then represents the volume actually sold to the purchaser. This volume may not agree with the mathematically determined total after all of the system operations are completed so a final allocation must be made to determine each well's share of the sale volume. This is accomplished by use of the "Allocation Base Function" illustrated in TABLE V and FIG. 6.

TABLE V

ALLOCATION BASE FUNCTION

MASTER FILE RECORD CODING SCHEME

ABSE	K	C_V	$A_1 \ldots . A_K$

ABSE = Operating Code

K = Number of Allocation Points Involved (K>0)

C_V = Column Name; Location of Beginning (Gross) Volume

$A_1 \ldots . A_K$ = Row Names; Allocation Points Involved

Referring to FIG. 6, values for K, C_V, and A are entered as shown in block 125. If K=0, the YES line is followed from decision point 126 and the subroutine is terminated. If K is something other than zero, the NO line is followed to block 127 where the initial index column is called. In block 128, the beginning volume is placed in the receiving position for point A and then the initial column index is compared with the final column index. If they are not equal, the following calculation is performed as per block 131.

$$VOL_{(BASE,\ A_1)} = VOL_{(BASE,\ A_1)} + VOL_{(X_1,\ A_1)} + VOL_{(X_n,\ A_1)}$$

where $X_1 \ldots . X_n$ = the disposition and receipt columns of the array.

When the initial index becomes equal to the final index (block 132), the YES branch is followed from the decision block which advances the index counters and repeats the process for points $A_2 \ldots . A_K$.

The coding for the Allocation Base Function would be as follows:

959169

ABSE/0026/MVOL/7W01/7W02/7W03/7W04/7W05/7W06/7W07
/7W08/7W09/7W10/7W11/7W12/7W13/7W14/7W15/7W16/7W17
/7W18/7W19/7W20/7W21/7W22/7W23/7W24/7W25/7W26

This coding tells the calculation program to call the Allocation Base Function and perform it with the above data. The program would take for each well in the system its metered gas volume and deduct from this each of the dispositions of gas chargeable to that well and come up with a remainder volume which represents theoretically what that well has available to sell at line 31a. These volumes then constitute the base on which the final allocation of sales volume is made to each contributing well using the actual metered sales volume in the Allocation Function.

Once the allocated sales volume for each well is determined, it may be desirable to determine each well owner's share of that gas. The "Ownership" Function shown in TABLE VI and FIG. 7 can be used for this purpose.

TABLE VI

OWNER INTEREST CALCULATION FUNCTION

MASTER FILE RECORD CODING SCHEME

OWNR	K	C_V	$A_1 \ldots A_K$

OWNR = Operating Code

K = Number of Allocation Points Involved (K>0)

C_V = Column Name; Location of Volume to be Split Among Owners

$A_1 \ldots A_K$ = Row Names; Allocation Points Involved

Referring to FIG. 7, the values for K, C_V, and A are tabled in block 135. The subroutine terminates at decision

point 136 if K=0. If K is not equal to zero, then some additional initializing of values and indexes takes place in block 137. The next decision point checks to see if the owner factor is zero. If it is, block 139 increases the index by one and following a test to assure that the indexed owner factor is not greater than the final owner factor (block 140), the process is repeated. If the condition of 140 tests true, indexes are increased and the routine returns to beginning, repeating for point A_2, etc.

In the case where the tested owner factor of block 138 is something other than zero, the logic proceeds to a further test (block 142) of the indexed owner factor compared to the final. If the test is passed at this point, the indication is that there is only one owner and the final calculation of block 143 is made and the indexes advanced to return for points A_2, etc.

If the test of block 142 fails, then further processing is indicated. The index of the owner factor is moved to a previously used index in block 144 and increased by one in block 145.

Then the owner index test is made again (block 146) with the same results as previously if the test passes.

If the test fails, this means that there are other owners to be considered and the calculation is made according to block 147. An intermediate volume is calculated by the following formula:

$$\text{ALOC VOL x OWNER FACTOR}_{n+1} = \text{I VOL}_1$$

This calculated volume is then added to the owner volume already present for owner_{n+1} and a second intermediate volume is calculated which is an accumulation of the I VOL_1 calculated above. This is used in the final calculation of block 143 to determine the first owner's share by difference.

Indexing is then performed as shown in block 141 so that the above sequence is repeated for points $A_2 \ldots A_K$.

The Ownership Function would be coded as follows:

OWNR/0026/AVOL/7W01/7W02/7W03/7W04/7W05/7W06/7W07 /7W08/7W09/7W10/7W11/7W12/7W13/7W14/7W15/7W16/7W17 /7W18/7W19/7W20/7W21/7W22/7W23/7W24/7W25/7W26

The participation factors of the various owners in each well were previously entered into the master file of the computer and are available for recall. In this instance the coding directs the calculation program to perform the Ownership Function with the indicated data. This would result in the division of the final allocated gas volume (AVOL) for each well in the system to each separate well owner in accordance with the percentage ownership which he has in the well.

Calculations similar to the above would be performed if the gas were going to the gas processing plant instead of directly to a transmission line. The flow through line 31b would be measured by meter m and the recorded volume allocated to each contributing well using the Allocation Base Function and the Allocation Function.

While the aforegoing has illustrated the application of the present invention to one specific embodiment, it is obvious from a consideration of the design concepts of the system that it is open-ended from the standpoint of the incorporation of additional general mathematical functions into the logic of the system. This may be done at any time a need arises which cannot be handled by the existing functions. It is also obvious that the number of allocation points which may be handled is also capable of being increased or decreased in any number, the only limit being the maximum size of the computer storage available.

In addition to the Allocation Function, the Point

Move Function, the Theoretical Volume Calculation Function, the Gas Lift Function, the Allocation Base Function, and Owner Interest Calculation Function already discussed, other general functions which have been employed by Applicants in regard to particular field gas systems include the following:

The "Volume Split Function" which divides composite volumes into two or more components based on ratios of certain special factors.

The "Column Move Function" which moves data items from one column to another in the array.

The "Row Move Function" which moves data from one row to another in the array.

The "Column Balance Function" which subtracts designated point values from a beginning value and stores the remainder at a selected point.

The "Row Balance Function" which subtracts a designated column value of a point from a beginning column value and places the answer in a selected location.

The "Allocation of Fuel Function" which is a special case of the Allocation Function in which the volume of fuel to be allocated is first calculated from a set formula.

The "Row Summation Function" in which the sum of various column data items appearing in one row is calculated and placed at a designated location.

The "Column Summation Function" in which the same function is performed for data items in one column of many rows or points.

The "Pressure Base Conversion Function" in which the standard pressure basis of gas measurement may be changed to conform to variations required by contract, state, or company differences.

The "Zero Function" which permits the elimination of

data from designated locations in the array within limits.

The "Assignment Function" which permits the special assignment or allocation of volumes to designated points depending upon predetermined conditions.

The "Multiple Element Row Balance Function" which performs the same function as the Row Balance Function except that more than one designated element may be subtracted.

The "Compare and Assign Function" which compares one value with another and makes calculation and assignment based on the result of the comparison.

The "Partial Owner Calculation Function" which permits the calculation of owner shares in an entities volume on a designated partial basis.

The present invention is also applicable to situations other than field gas allocation systems. For example, the invention can be used to great advantage in the case of gas processing plants. Many things occur within the confines of a gas processing plant which change the nature, quality and/or quantity of the gas stream being processed. All these events can be accounted for in allocation procedures similar to those presented for the field gathering system regardless of the nature of the plant or the conditions governing the processing of the gas and handling of the resulting products.

The allocation functions previously presented in conjunction with the field gas allocation system can be applied to a gas plant system, subject to certain modifications in array size, data content, and functions performed which will be obvious to those skilled in the art. (However, there is no need for the Gas Lift Function or the Allocation of Fuel Function.) Additionally, certain general functions which are uniquely associated with plant activities are given below:

The "Value Calculation Function" which permits the

calculation of the money value of various volumes of product and gas and the storage of these values in selected locations.

The "Tax Calculation Function" which performs the computation of various forms of taxes which must be deducted from gross values prior to determining the actual allocated values due leases or allocation points.

The "Hydrocarbon Shrinkage Calculation Function" which calculates from input factors the amount of shrinkage resulting in the gas stream from the removal of various hydrocarbon products from the stream.

The "Inventory Status Calculation Function" which calculates the position of inventory relative to sales and production and permits the determination of the source of disposed volumes of product and thus the price which is applicable.

The "Inventory Balance Function" which then takes the status and sales and production and calculates a new closing inventory for each product of the plant.

The present allocation systems have been coded in the Cobol computer language for use on IBM 360 computers, but it is obvious that the invention can be extended to other computer languages using any desired hardware and software systems. The complete software system consists of several conventional data processing programs for producing reports, sorting data, and changing record formats. In addition to these are the three programs which comprise the heart of the system by incorporating the concepts which have been explained. These are the master file maintenance program which keeps the data current and permits changes in the allocation procedures through file updating procedures. The second is the indexing program which provides the means of indexing or locating all data items within the computational array. The third is the

computational program itself which performs all the required manipulations and calculations and produces an output record of the results.

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959169

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A system for allocating gas and liquid products in conjunction with a field gas gathering and processing system comprising:

(a) a digital computer operable to solve allocation functions physically represented by electrical signals within said computer, said functions representing uses and dispositions of products encountered in said field gas gathering and processing system, and the relationship of the uses and dispositions to individual allocation points,

(b) means for metering gas flow at points of allocation and points of use and disposition in the gas gathering and processing system, and for generating an electrical signal applied to said digital computer relatable to the metered gas flow,

(c) means for generating within said digital computer signals representing a two-dimensional array, allocation point index terms being defined in one dimension and use and disposition index terms being defined in another dimension,

whereby said digital computer performs the mathematical calculations prescribed by the allocation functions in respect to the signals relatable to the metered gas flow, and stores signals representing results of the calculations in said array under appropriate index terms.

959169
6-1

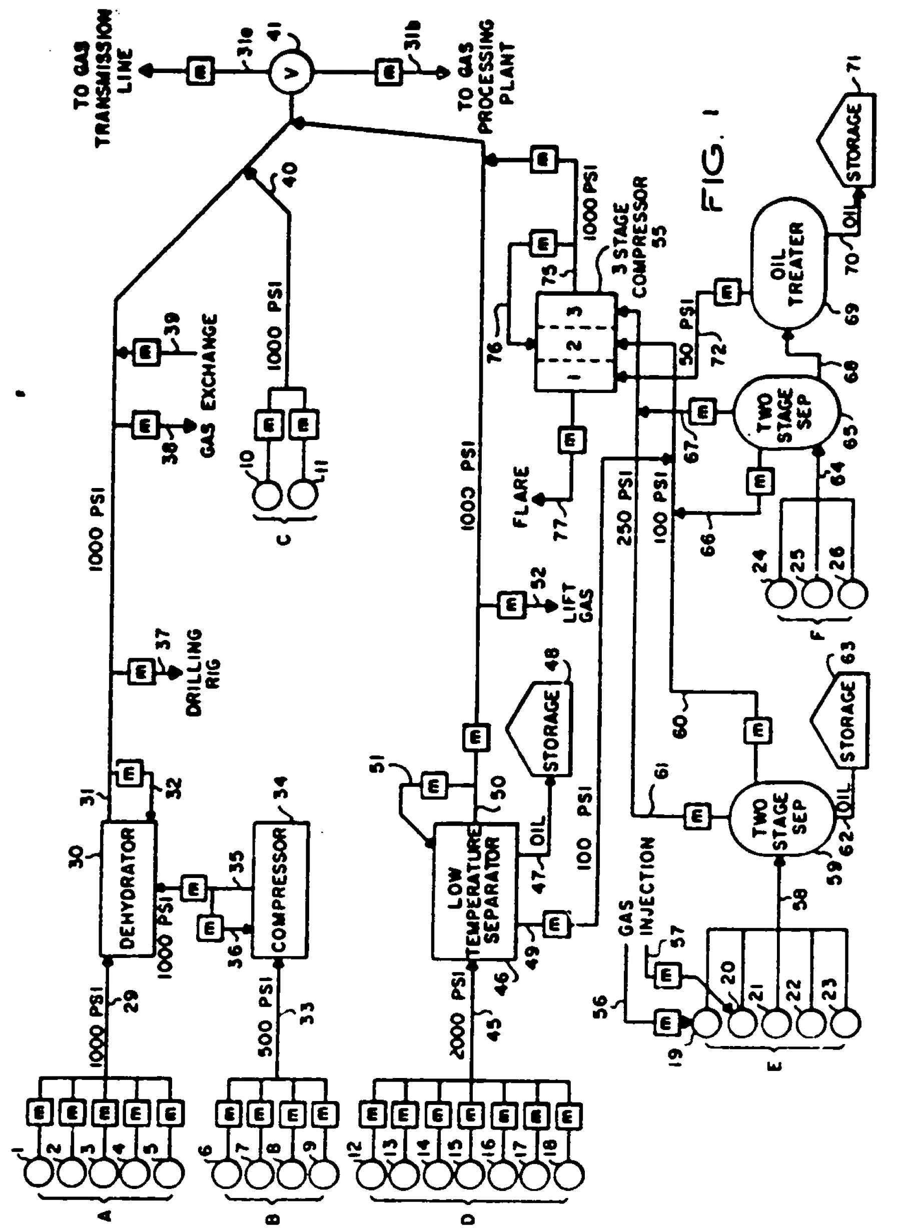

FIG. 1

959169
6-2

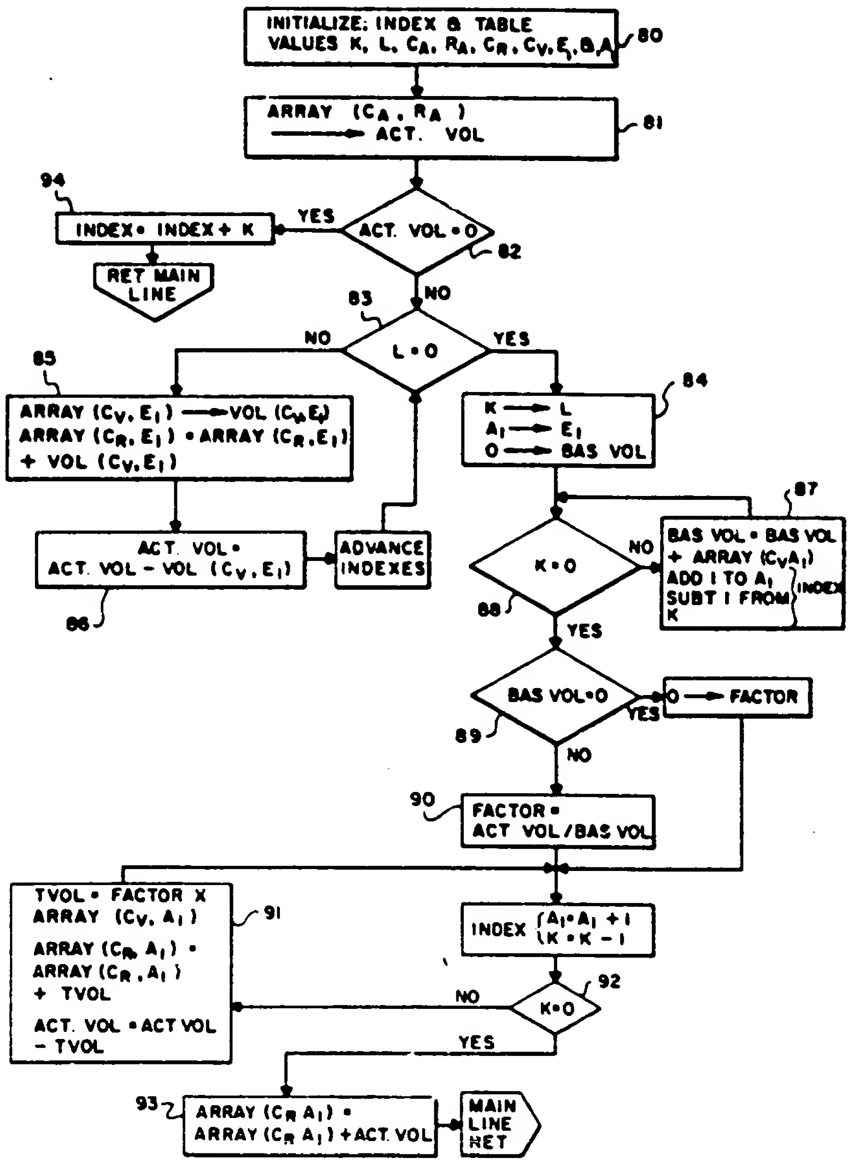

FIG. 2

959169
6-3

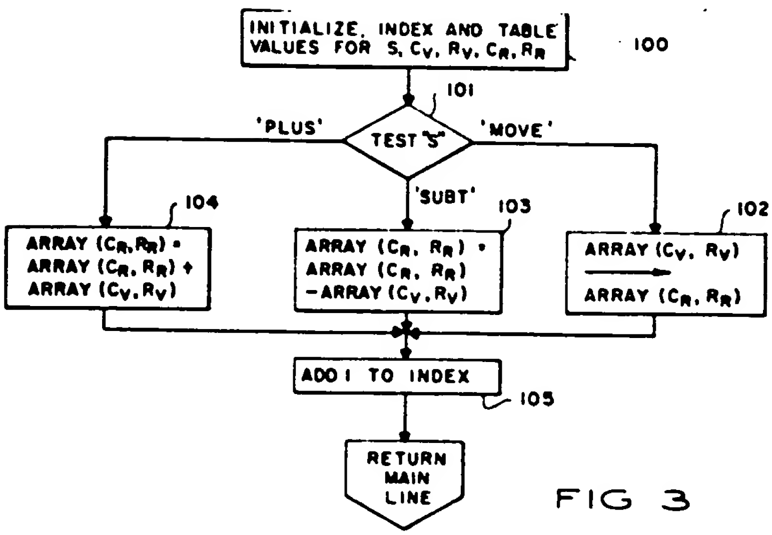

FIG 3

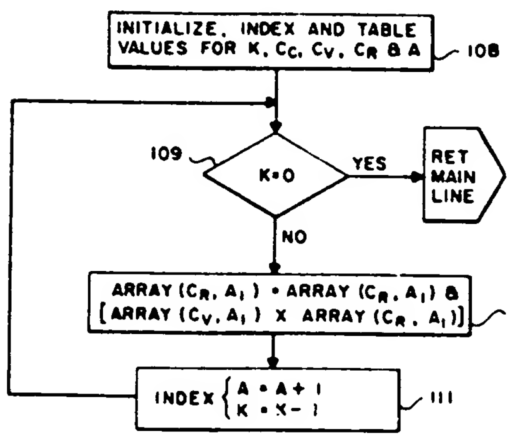

FIG 4

959169
64

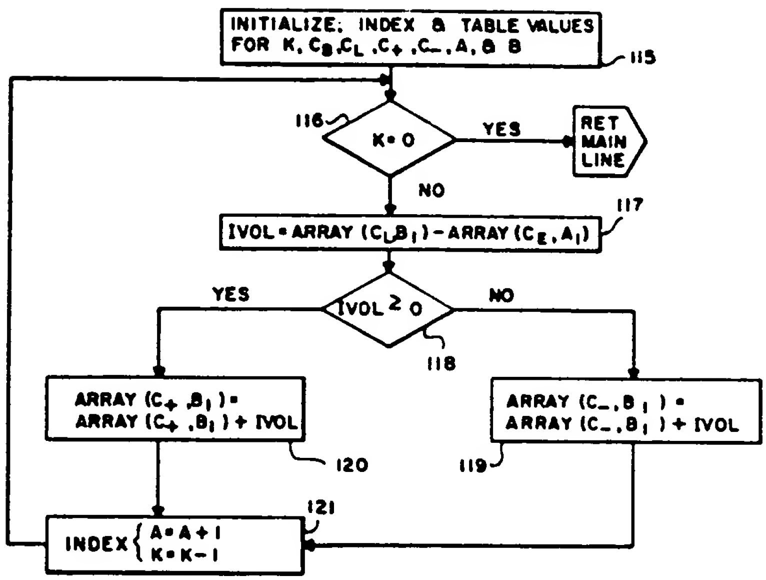

FIG. 5

959169
65

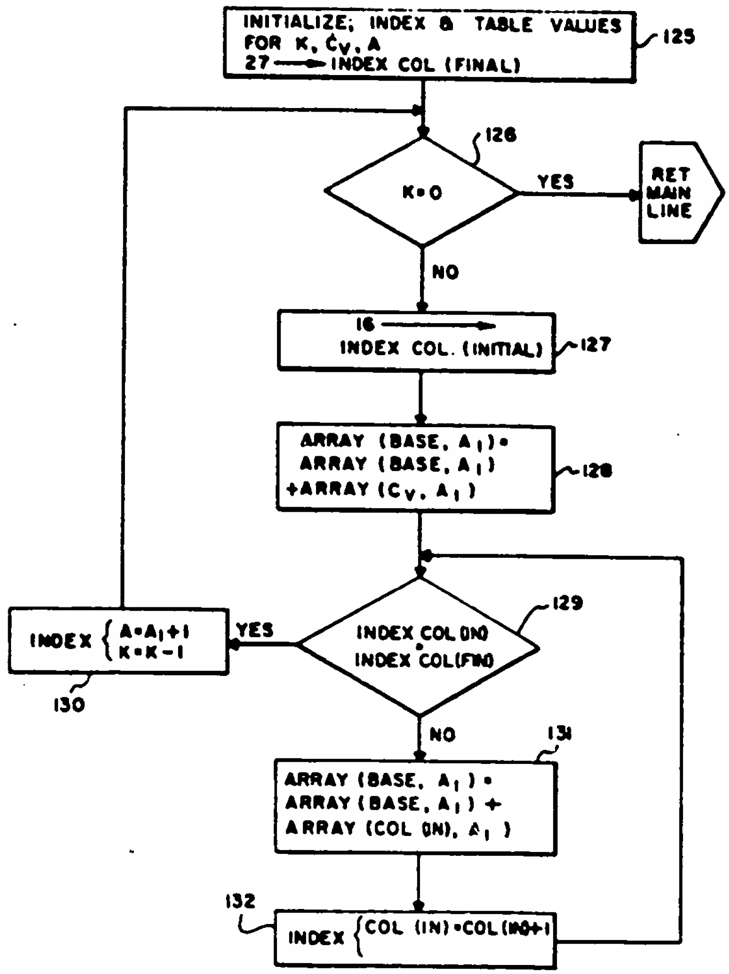

FIG. 6

959169

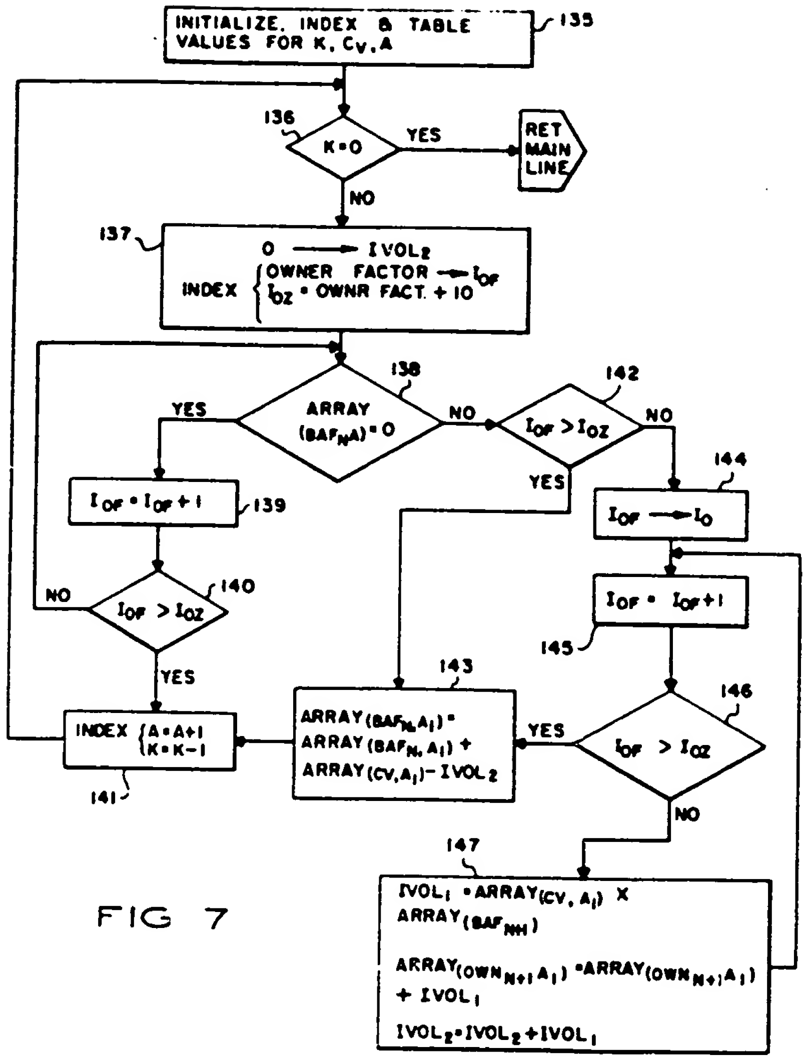
INITIALIZE. INDEX & TABLE VALUES FOR K, C_V, A
135
136
K=0
YES
RET MAIN LINE
NO
137
0 → $IVOL_2$
INDEX {OWNER FACTOR → I_{OF}
I_{OZ} = OWNR FACT. + 10
138
ARRAY (BAF_N,A) = 0
YES
NO
142
$I_{OF} > I_{OZ}$
NO
YES
144
I_{OF} → I_O
$I_{OF} = I_{OF}+1$
139
140
NO
$I_{OF} > I_{OZ}$
YES
$I_{OF} = I_{OF}+1$
145
143
146
INDEX {A=A+1 / K=K-1
141
ARRAY(BAF_N,A_I) = ARRAY (BAF_N, A_I) + ARRAY(CV,A_I) − $IVOL_2$
YES
$I_{OF} > I_{OZ}$
NO
147
$IVOL_I$ = ARRAY(CV, A_I) X ARRAY(BAF_{NH})
ARRAY(OWN_{N+1},A_I) = ARRAY(OWN_{N+1},A_I) + $IVOL_I$
$IVOL_2$ = $IVOL_2$ + $IVOL_I$

FIG 7